MILLER CONSTRUCTION, INC.

P.O. BOX 86 ASCUTNEY BLVD WINDSOR, VERMONT 05089-0086

TELEPHONE (802) 674-5525 / FAX (802) 674-5245

TRANSMITTAL

TO: Jennifer Fitch, PE Project Manager Vermont Agency of Transportation	DATE	PROJECT NO.
	11/10/2014	Brookfield BRF FLBR (2)

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COPIES	NUMBER	DESCRIPTION	CODE
1		Witness Panel Test Results	H

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I AS REQUESTED OR REQUIRED
J FOR USE IN ERECTION
K LETTER FOLLOWS
L FOR FIELD CHECK
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BY: 

Witness Panel Test Results for Brookfield Floating Bridge

Prepared for:

Paul Holloway
Miller Construction

Prepared by:

Jacob Marquis
Kenway Corporation

November 7, 2014

The attached test report dated October 20, 2014 documents mechanical and physical tests required by the special provision specification performed by UMaine on selected Witness Panels 2, 3 and 8. A summary of the test data is provided below.

Physical and mechanical tests noted below in Tables 1 and 2 were performed on witness panels selected from Pontoons 2, 3, and 8 infusions. A comparison relative to baseline values derived during qualification testing is also provided.

Table 1: Mechanical Test Results

	Flex Str	Delta	Flex Mod	Delta	Bearing	Delta
Baseline	52	n/a	2.6	n/a	53	n/a
WP2	47	-9%	2.2	-15%	29	-45%
WP3	50	-3%	2.5	-3%	33	-38%
WP8	44	-15%	2.1	-19%	32	-40%

Table 2: Physical Test Results

	Absorp.	Delta	Fiber Wt	Delta	Density	Delta
Baseline	0.10%	n/a	71%	n/a	0.068	n/a
WP2	0.05%	-50%	69%	-2%	0.067	-1%
WP3	0.03%	-70%	72%	2%	0.069	1%
WP8	0.05%	-50%	69%	-2%	0.067	-1%

Flexural strength and modulus results are up to 15% and 19% below baseline values, respectively, to as little as 3% below baseline. The flexural test is used as a relative assessment during fabrication to monitor deviations throughout production since it induces a combination of loads and stresses. Once the lower strength and stiffness were identified, Kenway reviewed the design calculations to determine which computations, if any, were close (within 20%) to the allowable values. Of the 32 load cases evaluated, only one is affected by the potential strength and stiffness reduction indicated by the flexural test results - net tension in the top and bottom flanges. Kenway decided to have tensile tests performed on specimens taken from the witness panels to obtain a strength value that could be compared to the design value and, if lower, used to assess the impact. See Table 3 for results, which show strength is only 1-11% below baseline value and modulus exceeds baseline value up to 19%. UMaine test results are attached as an addendum to the original witness panel test report.

Bearing strength results are as much as 45% below the baseline value. There was serious concern prior to testing that results obtained from a nominal 1/4 in. witness panel laminate would illustrate significant size effects when compared to tests performed on the baseline laminate thickness of 1 in. Since 1 in. thick witness panels were not fabricated with each pontoon, a demonstration could be performed on a thick and thin panel if warranted. In this demonstration, a 1/4 in. panel and a 1 in. panel would be fabricated at the same time and tested for bearing

strength to qualify the observed size effect and show that the 1 in. thick panel can achieve the previously tested baseline bearing strength of 53 ksi.

Table 3: Tensile Test Results

	Strength	Delta	Modulus	Delta
Baseline	46.7	n/a	3.09	n/a
WP2	46.3	-1%	3.65	18%
WP3	41.4	-11%	3.69	19%
WP8	44.1	-6%	3.52	14%

Assuming the witness panels are indicative of the full thickness components, the following calculation is the only instance where the factored resistance is within 20% of the factored load. (See approved design calculations with baseline test results dated 5/19/14.)

Original Calculation Impacted by Lower Test Results

Net tension in top and bottom flanges

$$R_{nt} = \frac{1}{K_{nt,L}}\left(w - nd_n\right)tF_L^t$$

$$K_{nt,L} = C_L\left(S_{pr} - 1.5\frac{\left(S_{pr}-1\right)}{\left(S_{pr}+1\right)}\Theta\right) + 1$$

t =	0.950	in	(plate thk)		n =	3	
d_n =	0.938	in	(dia. +1/16)		w =	10.5	(3 x g)
F_L =	39.69	ksi	(ten. stren.)		g =	3.5	
C_L =	0.40		46.7 x 0.85 Moist. Factor		$K_{nt,L}$ =	2.24	
λ =	0.90				S_{pr} =	4.00	(g/d)
ϕ =	0.50				Θ =	1.0	($e_1/g \geq 1$)
C_Δ =	1.0						
$\lambda\phi R_n$ =	58.23	kip	>	R_u =	58.20	kip	(Sheet 38)
					(3 x 19.4)		

The equivalent safety factor based on the design load and resistance factors including the ratio of predicted to allowable load is

1.4 / (0.85x0.4x0.9x0.5) x (58.23/58.20) = 9.2.

The lowest measured tensile strength of 41.4 ksi is substituted into the revised calculation below.

Revised Calculation Impacted by Lower Test Results

Net tension in top and bottom flanges

$$R_{nt} = \frac{1}{K_{nt,L}}(w - nd_n)tF_L'$$

$$K_{nt,L} = C_L\left(S_{pr} - 1.5\frac{(S_{pr}-1)}{(S_{pr}+1)}\Theta\right) + 1$$

t =	0.950	in	(plate thk)		n =	3	
d_n =	0.938	in	(dia. +1/16)		w =	10.5	(3 x g)
F_L =	35.19	ksi	(ten. stren.)		g =	3.5	
C_L =	0.40		41.4 x 0.85 Moist. Factor		$K_{nt,L}$ =	2.24	
λ =	0.90				S_{pr} =	4.00	(g/d)
ϕ =	0.50				Θ =	1.0	(e_1/g ≥ 1)
C_Δ =	1.0						
λϕR_n =	51.63	kip	>		R_u =	58.20 *(3 x 19.4)*	kip (Sheet 38)

The equivalent safety factor based on the load and resistance factors including the ratio of predicted to allowable load is

1.4 / (0.85x0.4x0.9x0.5) x (51.63/58.20) = 8.1.

Based on the minor impact to overall functionality and safety – a significant safety factor still exists – Kenway requests that the witness panel test data be accepted as is.

Witness Panel Material Property Testing for Vtrans Floating Bridge

Prepared for:

Jake Marquis
Kenway Corporation
Augusta, Maine

University of Maine's Advanced Structures and Composites Center
Report Number: 15-11-1267

October 20, 2014

Prepared by:
Olivia Sanchez
Research Engineer

Reviewed by:
Dr. Douglas Gardner
Professor of Wood Science and Technology

ACCREDITED

An ISO 17025 accredited testing laboratory, accredited by the International Accreditation Service.

Project Number: 1267
Project Date: October 20, 2014
Material: E-Glass/Interplastics 8100-50 Vinyl Ester
Date Received: September 29, 2014

Project Summary: The following material property tests were conducted:

- ASTM D7264 - *Standard Test Methods for Flexural Properties of Polymer Matrix Composite Materials*
- ASTM D953 - *Standard Test Method for Bearing Strength of Plastics*
- ASTM D570 - *Standard Test Method for Water Absorption of Plastics*
- ASTM D2584 - *Ignition Loss of Cured Reinforced Resins*
- ASTM D792 – *Density of Plastics*

The client provided three composite panels each 24 inch by 24 inch with nominal thickness of 0.22 inches.

The standard pontoon laminate will consist of (1) 4008 ±45, (7) 5400 0/90, and (1) 4008 ±45. This results in a total fabric areal weight of 474 oz./yd^2 (16 oz./yd^2 stitched mat (3%), 80 oz./yd^2 ±45 (17%), 378 oz./yd^2 0/90 (80%)) and a total thickness of 0.508 inches. The laminate schedule for the 0.22 inch test panels was derived to provide a similar ratio of fiber orientations while resulting in a thickness of less than 0.250-inch. The test laminate consists of (1) 1708, (3) 5400, and (1) 1708, which has a total areal weight of 214 oz./yd^2 (16 oz./yd^2 stitched mat (7%), 36 oz./yd^2 ±45 (17%), and 162 oz./yd^2 0/90 (76%)). Because of the test laminate having a greater percentage of stitched-mat (non-structural fiber); mechanical testing will produce strength and stiffness values that are lower than the and therefore will be conservative estimates of strength and stiffness for the actual pontoon laminate.

All test specimens were cut from the panels using a water-cooled diamond-coated wet-saw. Final specimen drilling and machining was performed using a milling machine.

Prior to conducting the tests, the specimens were conditioned for a minimum of 48-hours in the laboratory's Mechanical Testing Lab at a standard environment of 70 ±3°F and 50 ±5% RH. The testing was also performed in this Lab at the standard environmental conditions.

The results of the various tests are summarized in the remainder of this document.

Material Property Test: Flexure
Test Method: ASTM D7264 - *Standard Test Method for Flexural Properties of Polymer Matrix Composite Materials*
Date Tested: October 15, 2014

Test Setup: Five specimens were obtained from each panel. The nominal specimen size was 1.0 inch wide by 8.5 inches long.

An electric screw Instron test frame equipped with a 2-kip load cell and a 3-point flexure fixture with a support span of 7.026 inches were used during the flexure tests. The tests were conducted in position control at a cross-head rate of 0.10 inches/minute.

Results: The specimen dimensions and results of the flexure tests are presented in Table 1. The table includes the average value and CV for the flexural strength and modulus. The modulus was computed between 1000-3000 micro-strains.

Table 1. Flexure Test Results

Specimen #	Width (in)	Thickness (in)	Max Load (lbs)	Max Stress (psi)	Modulus (Msi)
WP2-1	1.009	0.235	255	48	2.19
WP2-2	0.999	0.236	247	47	2.19
WP2-3	1.008	0.238	248	45	2.01
WP2-4	1.014	0.240	251	45	2.14
WP2-5	1.007	0.228	239	48	2.35
Average	*1.0*	*0.2*	*248*	*47*	*2.2*
COV	*0.5%*	*2.0%*	*2.3%*	*3.0%*	*5.7%*
Specimen #	**Width (in)**	**Thickness (in)**	**Max Load (lbs)**	**Max Stress (psi)**	**Modulus (Msi)**
WP3-1	1.010	0.230	260	51	2.57
WP3-2	1.008	0.232	257	50	2.53
WP3-3	1.010	0.232	265	51	2.55
WP3-4	1.009	0.236	261	49	2.38
WP3-5	1.003	0.232	260	51	2.49
Average	*1.0*	*0.2*	*261*	*50*	*2.5*
COV	*0.3%*	*1.0%*	*1.1%*	*2.1%*	*3.0%*
Specimen #	**Width (in)**	**Thickness (in)**	**Max Load (lbs)**	**Max Stress (psi)**	**Modulus (Msi)**
WP8-1	1.012	0.261	286	44	2.09
WP8-2	1.010	0.255	287	46	2.21
WP8-3	1.017	0.259	273	42	1.99
WP8-4	0.996	0.253	269	44	2.13
WP8-5	1.010	0.252	262	43	2.18
Average	*1.0*	*0.3*	*275*	*44*	*2.1*
COV	*0.8%*	*1.5%*	*3.9%*	*3.3%*	*4.0%*

Equipment used:

- Mitutoyo Caliper AS# 685
- Instron 2-kip Test Frame AS# 1155
- 2-kip Load Cell AS# 1156
- Flexure Fixture AS# 1155-F

Material Property Test: Bearing
Test Method: ASTM D953 - *Standard Test Method for Bearing Strength of Plastics*
Date Tested: October 17, 2014

Test Setup: Five specimens were obtained from each panel. The nominal specimen size was 4 inches wide by 10.5 inches long.

A servo-hydraulic Instron test frame equipped with a 22-kip load cell and hydraulic grips was used to perform the tests. A pin-bearing fixture was used to support the specimen at one end while load was applied to the 15/16 inch hole via a 7/8 inch hardened steel pin at the other end. The tests were conducted in position control at a cross-head rate of 0.05 inches/minute.

Results: The specimen dimensions and results of the bearing tests are presented in Table 2. The Table includes the average value and CV for the bearing strength at the first drop in load and at the ultimate load.

Table 2. Bearing Strength Test Results

Specimen #	Thickness (in)	Bearing Area (in^2)	Force		Strength	
			First Drop (lbs)	Ultimate (lbs)	First Drop (ksi)	Ultimate (ksi)
WP2-A	0.2387	0.2238	n/a	6157	*	27.52
WP2-B	0.2383	0.2234	6188	7458	27.69	33.38
WP2-C	0.2387	0.2238	4710	5967	21.05	26.67
WP2-D	0.2407	0.2256	6207	6722	27.51	29.79
WP2-E	*0.2348*	0.2202	*5319*	*6465*	24.16	29.36
Average	*0.2*	*0.2*	*5606*	*6554*	*25.10*	*29.34*
COV	1%	1%	13%	9%	0.13	0.09

* Software stopped test prior to ulimtate loading

Specimen #	Thickness (in)	Bearing Area (in^2)	Force		Strength	
			First Drop (lbs)	Ultimate (lbs)	First Drop (ksi)	Ultimate (ksi)
WP3-A	0.2310	0.2166	6178	6986	28.53	32.26
WP3-B	0.2378	0.2230	5205	6594	23.34	29.57
WP3-C	0.2345	0.2198	4997	7843	22.73	35.67
WP3-D	0.2330	0.2184	5520	6298	25.27	28.83
WP3-E	*0.2327*	0.2181	*4919*	*8009*	22.55	36.72
Average	*0.2*	*0.2*	*5364*	*7146*	*24.49*	*32.61*
COV	1%	1%	10%	11%	0.10	0.11

Specimen #	Thickness (in)	Bearing Area (in^2)	Force		Strength	
			First Drop (lbs)	Ultimate (lbs)	First Drop (ksi)	Ultimate (ksi)
WP8-A	0.2673	0.2506	6475	7793	25.84	31.09
WP8-B	0.2560	0.2400	5642	7628	23.51	31.78
WP8-C	0.2573	0.2413	6471	7559	26.82	31.33
WP8-D	0.2537	0.2378	5874	7865	24.70	33.07
WP8-E	*0.2587*	0.2425	*6204*	*7863*	25.58	32.43
Average	*0.3*	*0.2*	*6133*	*7742*	*25.29*	*31.94*
COV	2%	2%	6%	2%	0.05	0.03

Equipment used:

- Mitutoyo Caliper AS# 685
- Instron 22-kipTest Frame AS# 107
- 22-kip Load Cell AS# 268

Material Property Test: Water Absorption
Test Method: ASTM D570 - *Standard Test Method for Water Absorption of Plastics*
Date Tested: October 13, 2014

Test Setup: Five specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 1.0 inch wide by 3.0 inches long. The specimens were weighed while dry and then submerged in a bath of deionized water in a standard environment.

Results: The results of the 24-hr soak are presented in Table 3. The table includes the mean value and CV for the water absorption of the specimens.

Table 3. Water Absorption Test Results

Specimen #	Length (in)	Width (in)	Thickness (in)	Dry Weight (g)	24hr Weight (g)	% Water Absorption
WP2-1	3.013	1.003	0.244	20.7531	20.7633	0.05%
WP2-2	3.005	1.008	0.231	20.5701	20.5800	0.05%
WP2-3	3.019	1.016	0.234	20.5440	20.5530	0.04%
WP2-4	3.020	1.006	0.228	20.0987	20.0955	*
WP2-5	2.989	1.012	0.234	20.3835	20.3923	0.04%
Average	3.009	1.009	0.234	20.4699	20.4768	0.05%
COV	0.42%	0.51%	2.53%	1.20%	0.74%	6.54%
Specimen #	**Length (in)**	**Width (in)**	**Thickness (in)**	**Dry Weight (g)**	**24hr**	**% Water Absorption**
WP3-1	2.999	1.011	0.231	21.0498	21.0558	0.03%
WP3-2	2.999	1.011	0.237	21.4313	21.4400	0.04%
WP3-3	3.009	1.011	0.230	21.0712	21.0775	0.03%
WP3-4	3.010	1.012	0.230	20.8848	20.8904	0.03%
WP3-5	3.010	1.015	0.236	21.3646	21.3711	0.03%
Average	3.005	1.012	0.233	21.1603	21.1670	0.03%
COV	0.20%	0.19%	1.37%	1.09%	1.09%	17.31%
Specimen #	**Length (in)**	**Width (in)**	**Thickness (in)**	**Dry Weight (g)**	**24hr**	**% Water Absorption**
WP8-1	3.010	1.011	0.249	22.2345	22.2471	0.06%
WP8-2	3.010	1.010	0.256	22.3529	22.3652	0.04%
WP8-3	3.016	1.006	0.255	22.4175	22.4273	0.05%
WP8-4	3.012	1.012	0.252	22.1442	22.1548	0.04%
WP8-5	3.015	1.011	0.254	22.1757	22.1848	0.05%
Average	3.012	1.010	0.253	22.2650	22.2758	0.05%
COV	0.09%	0.23%	1.19%	0.52%	0.49%	10.01%

Equipment used:

- Mitutoyo Caliper AS# 685
- Ohaus Scale AS# 657

Material Property Test: Fiber Volume Fraction
Test Method: ASTM D2584 - *Ignition Loss of Cured Reinforced Resins* and
ASTM D792 – *Density of Plastics*
Date Tested: October 15, 2014

Test Setup: Five specimens were cut from each panel and used to determine the density of the laminate, followed by the determination of the fiber volume content. The density specimens were weighed in air followed by being weighed while being submersed in water.

The specimens were dried in an oven at 100 °F for 8 hours prior to determining the fiber volume content. The specimens were placed and weighed in a ceramic crucible before being placed in a muffle furnace at 565 °C until the matrix was burned off.

Results: The results of the density and fiber volume content are presented in Table 4. The table includes the mean value and CV.

Table 4. Density and Fiber Volume Results

Specimen #	Length (in)	Width (in)	Thickness (in)	Density (pcf)	Fiber Volume
WP2-1	1.489	1.014	0.227	0.0670	69.6%
WP2-2	1.484	1.005	0.245	0.0664	69.0%
WP2-3	1.487	1.009	0.241	0.0660	68.5%
WP2-4	1.488	1.008	0.234	0.0668	69.4%
WP2-5	1.492	1.014	0.237	0.0667	69.0%
Average	1.488	1.010	0.237	0.0666	69%
COV	0.21%	0.40%	2.91%	0.61%	0.59%
Specimen #	**Length (in)**	**Width (in)**	**Thickness (in)**	**Density (pcf)**	**Fiber Volume**
WP3-1	1.492	1.019	0.234	0.0683	71.5%
WP3-2	1.487	1.012	0.235	0.0689	72.3%
WP3-3	1.493	0.991	0.239	0.0684	71.8%
WP3-4	1.493	1.016	0.240	0.0683	71.6%
WP3-5	1.492	1.014	0.232	0.0690	71.9%
Average	1.491	1.010	0.236	0.0686	72%
COV	0.16%	1.09%	1.37%	0.50%	0.43%
Specimen #	**Length (in)**	**Width (in)**	**Thickness (in)**	**Density (pcf)**	**Fiber Volume**
WP8-1	1.491	1.009	0.251	0.0669	69.2%
WP8-2	1.492	1.009	0.257	0.0660	69.2%
WP8-3	1.491	1.010	0.254	0.0667	69.3%
WP8-4	1.489	1.012	0.260	0.0668	69.0%
WP8-5	1.487	1.012	0.258	0.0667	68.8%
Average	1.490	1.010	0.256	0.0666	69%
COV	0.13%	0.16%	1.40%	0.51%	0.30%

Equipment used:

- Mitutoyo Caliper AS# 685
- Ohaus Scale AS# 657
- Muffle Furnace AS#180

Witness Panel Material Property Testing for Vermont Agency of Transportation Floating Bridge

Tensile Strength Test

Prepared for:

Jake Marquis
Kenway Corporation
Augusta, Maine

University of Maine's Advanced Structures and Composites Center
Report Number: 15-11-1267 Addendum

November 7, 2014

Prepared by:

Olivia Sanchez
Research Engineer

ACCREDITED

An ISO 17025 accredited testing laboratory, accredited by the International Accreditation Service.

Project Number: 1267
Project Date: November 2014
Material: E-Glass/Interplastics 8100-50 Vinyl Ester
Date Received: September 29, 2014

Project Summary: The following material property tests were conducted:

- ASTM D3039 - *Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*

The client provided three composite panels each 24-inch by 24 inch with nominal thickness of 0.22 inches.

Prior to conducting the tests, the specimens were conditioned for a minimum of 48-hours in the laboratory's Mechanical Testing Lab at a standard environment of 70 ±3°F and 50 ±5% RH. The testing was also performed in this Lab at standard environment.

The results of the test are summarized in the remainder of this document.

Material Property Test: Tension
Test Method: ASTM D3039 - *Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*
Date Tested: November 4, 2014

Test Setup: Five (5) specimens were obtained from the three (3) witness panels that were each nominally 1.0 inch wide by 10 inches long.

A servo-hydraulic Instron test frame equipped with a 22 kip load cell and hydraulic grips was used to perform the tests. The tests were conducted in position control at a cross-head rate of 0.05 inches/minute. A contact extensometer with a gage length of 2.0 inches was used to measure the strain.

Results: The specimen dimensions and results of the tensile tests are presented in Table 1. The table includes the average value and coefficient of variation (CV) for the tensile strength and modulus. The modulus was computed between 1000-3000 micro-strain.

Table 1. Tension Test Results

Specimen ID	Avg. Width (in)	Avg. Thickness (in)	Area (in^2)	Max Load (lbs)	Stress (psi)	MOE (msi)
WP2-1	0.955	0.236	0.225	10719	47575	3.32
WP2-2	0.965	0.239	0.230	10967	48676	3.85
WP2-3	0.962	0.245	0.236	10130	44964	3.81
WP2-4	0.965	0.245	0.237	10377	46061	3.38
WP2-5	0.965	0.250	0.241	9980	44295	3.89
Average	0.9624	0.2429	0.2338	10435	46314	3.65
Stdev	0.0042	0.0055	0.0060	408	1812	0.28
COV	0.4%	2.3%	2.6%	3.9%	3.9%	7.6%

Specimen ID	Avg. Width (in)	Avg. Thickness (in)	Area (in^2)	Max Load (lbs)	Stress (psi)	MOE (msi)
WP3-1	0.964	0.240	0.231	9304	40277	3.71
WP3-2	0.966	0.243	0.234	9547	41328	3.72
WP3-3	0.967	0.236	0.228	9710	42034	3.83
WP3-4	0.966	0.237	0.228	9654	41791	3.29
WP3-5	0.966	0.238	0.230	9385	40627	3.89
average	0.9656	0.2386	0.2304	9520	41445	3.69
stdev	0.0011	0.0028	0.0026	173	619	0.24
cov	0.1%	1.2%	1.1%	1.8%	1.5%	6.4%

Specimen ID	Avg. Width (in)	Avg. Thickness (in)	Area (in^2)	Max Load (lbs)	Stress (psi)	MOE (msi)
WP8-1	0.966	0.254	0.246	11212	45621	3.70
WP8-2	0.964	0.252	0.242	11006	44782	3.20
WP8-3	0.966	0.253	0.244	10289	41865	3.58
WP8-4	0.967	0.252	0.243	6754	27481	3.62
WP8-5	0.966	0.251	0.242	10822	44031	3.48
average	0.9657	0.2523	0.2436	10832	44075	3.52
stdev	0.0011	0.0013	0.0014	396	1610	0.19
cov	0.1%	0.5%	0.6%	3.7%	3.7%	5.5%

Equipment used:

- Mitutoyo Caliper AS# 565
- Mitutoyo Micrometer AS# 1200
- Instron 22-kip Test Frame AS# 108
- 22-kip Load Cell AS# 269
- Instron Extensometer AS# 566